RELATIONSHIP OF CELL DEPTH AND SOIL MOISTURE IN *OXYBELUS BIPUNCTATUS* (HYMENOPTERA: SPHECIDAE)[1]

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ABSTRACT: Nests of *Oxybelus bipunctatus* were excavated and cell depth measured in control and experimentally watered plots in a recently bulldozed sandy field in central New York in June 1987. There was a trend for cell depth to be inversely related to soil moisture under natural conditions and in artificially watered replicates.

Soil moisture content is extremely critical for the survival of the immature stages of ground inhabiting solitary wasps. Too little moisture in the soil results in dessication of the paralyzed prey in the cells and the eventual death of the wasp egg or larva. Too much soil moisture increases the likelihood of mold development in the cell and this, too, can destroy the cell contents and wasp egg or larva. A delicate balance in the amount of soil moisture is necessary for the immature stages of the wasps to develop properly. Many physical and biotic factors influence soil moisture content and regulate cell environment. Cell depth and amount of precipitation are two such factors that can be readily measured without elaborate or expensive equipment. The present study is an attempt to investigate the relationship between the amount of rainfall, depth of soil moisture line, and cell depth in a ground-nesting sphecid, *Oxybelus bipunctatus* Olivier.

Oxybelus bipunctatus, a species adventive from Europe (Pate 1943, 1945; Krombein 1979; Kurczewski 1998), is one of the most common digger wasps in the northeastern U. S. (Kurczewski and Harris 1968; Kurczewski and Acciavatti 1990). Ubiquity in nesting habitat, a long and continuous flight period involving two or three generations per year, and high nest density make this species an excellent subject for studying nesting behavior in a solitary wasp. Peckham et al. (1973) investigated the behavior of *O. bipunctatus* over three years. Although they carefully measured nest dimensions, these authors did not examine the relationship between cell depth and soil moisture content. Kurczewski (1996) noted the difference in cell depth of *O. bipunctatus* between localities in central New York and northwestern Pennsylvania but he, too, did not account for soil moisture level. In a 15 weeks-long investigation of *O. bipunctatus* at a site in upstate New York, the same author (in prep.) observed weekly fluctuation in cell depth that seemed to be linked to soil moisture level

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as influenced by the amount of rainfall. The present study is an extension of this finding. Using measurements of rainfall, soil moisture line, and cell depth, we tried to corroborate Kurczewski's (in prep.) results. By artificially adding water to designated sand plots, we attempted to demonstrate a relationship between soil moisture content and cell depth.

MATERIALS AND METHODS

A recently bulldozed sandy field in northwestern Madison County, New York, 5.6 km NW of Chittenango, a site used previously by Spofford et al. (1986) for a study on the cleptoparasites of another sphecid, *Tachysphex terminatus* (Smith), was selected as the study area. Natural conditions were monitored during 5-15 June 1987. This involved collecting and measuring the amount of rainfall from the previous day(s) and/or night(s) in mm, taking air (shade), sand surface and cell depth temperature in degrees C, and noting any change or disturbance to the area. Morning activity of individual wasps was correlated with air and cell depth temperature.

Females were observed digging burrows in the morning on 5, 6, 10, 11, and 14 June 1987, and their nest entrances were marked with color-coded toothpicks after completion of the temporary nest closures. (The wasps themselves were too small to color-code).

The cells were excavated the following morning or afternoon after the wasps completed their final closures, measurements were taken, and new nests were found and marked for the next day, weather permitting.

The relationship between cell depth and soil moisture line, a readily visible band of dark moist sand underlying a layer of light colored dry sand (Kurczewski in prep.), was examined for 35 of the cells. Depths of soil moisure line and cell to its bottom were measured with a metric ruler and recorded in mm. Depths of 53 other cells were also measured and recorded. Each excavation was then levelled flush with the surrounding sand and lightly packed down to encourage renesting.

Two areas of bare sand of equal size were selected and each area divided into control and experimental plots (Fig. 1). The selection of these areas was based upon local topography, lack of vegetation, and density of nesting wasps. One area was divided in half by a north-south line into 240 X 280 cm plots and labelled NC (North Control) and NE (North Experimental). The other area was divided in half by an east-west line into 480 X 140 cm plots and labelled SC (South Control) and SE (South Experimental). The direction of division into control and experimental plots coincided with slight slopes in the respective areas and was an attempt to eliminate any variables.

On June 16, we artificially watered the experimental plots to achieve a soil moisture level sufficiently higher than that in the control plots yet not inhibit

wasp excavation or create soil surface run-off. Using a 1.5 gal sprinkling can, we evenly applied 10 gallons of water to each experimental area in rows 20 cm wide beginning at 0920 hrs (EDT). Prior to watering, five 50 ml plastic graduated cylinders were set into the sand in each experimental plot, four of them each 30 cm in from a corner and one directly in the center of the plot (Fig. 1).

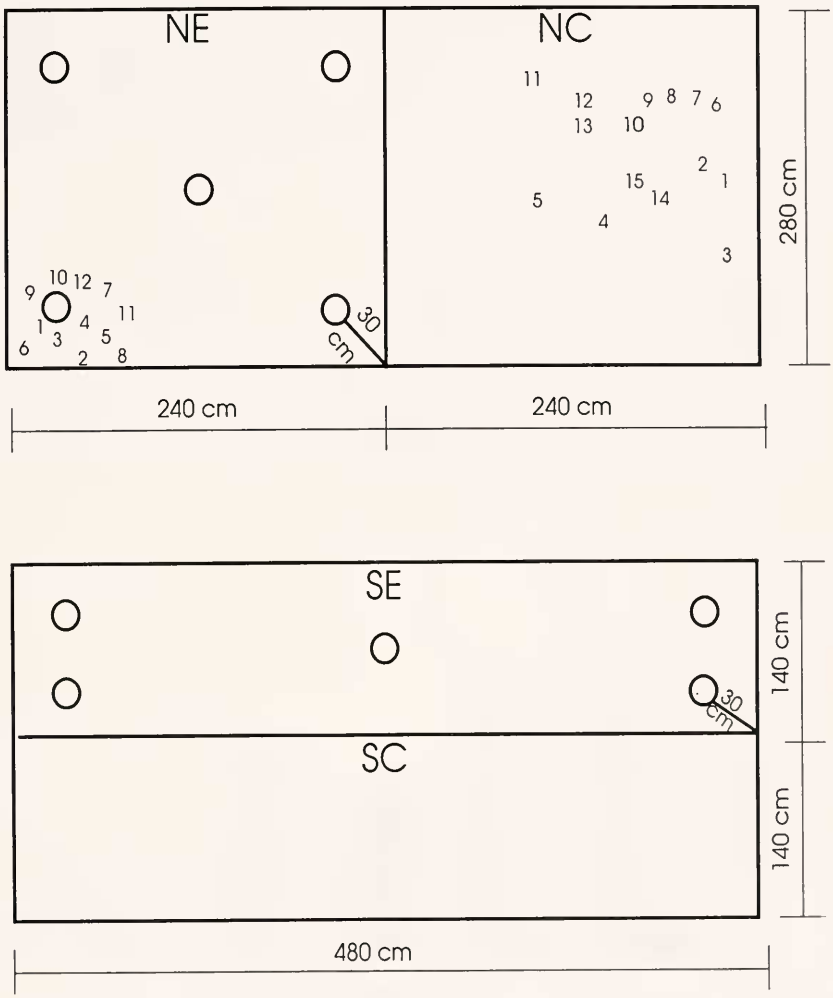

Fig. 1. Design of control (NC, SC) and experimental (NE, SE) plots in *Oxybelus bipunctatus* study area. Circles represent graduated cylinders set into sand to collect water. Numbers in NE and NC are locations of nest entrances sequentially marked on 24 June 1987.

The relative uniformity of our watering technique was reflected in the amount of water collected by the graduated cylinders: (NE), 4.0, 4.5, 6.0 (central), 5.0, 5.0 ml; and, (SE), 5.0, 4.0, 4.0 (central), 4.5, 5.0 ml.

On 24 June, we applied 20 gal of water to the NE plot utilizing the same technique, except the application was made between 2000-2100 hrs. We felt that an application at dusk would substantially decrease water evaporation from the sand surface and, by doubling the amount of water put into the soil, the wasps might dig significantly shallower nests in this plot. After the application, each of the five plastic graduated cylinders placed in the plot contained 7.5-8.0 ml of water. We intended to similarly water the SE plot the same evening, but it had been severely disturbed the previous night by a truck carrying a bulldozer and was abandoned for further use.

RESULTS

Temperature and rainfall. Only five of the 11 days (see above) set aside to study *O. bipunctatus* under natural conditions were suitable for wasp nesting. During these days, air temperatures averaged 22.8° C (18-25° C, n=5) and soil temperatures at cell depth averaged 26.7° C (23-31° C, n=5) at 1100 hrs (EDT). The six other days set aside for study under natural conditions were non-conducive for wasp nesting because of cool temperatures, cloud cover, and rain. It rained sporadically in three and heavily during two of the days (Fig. 2).

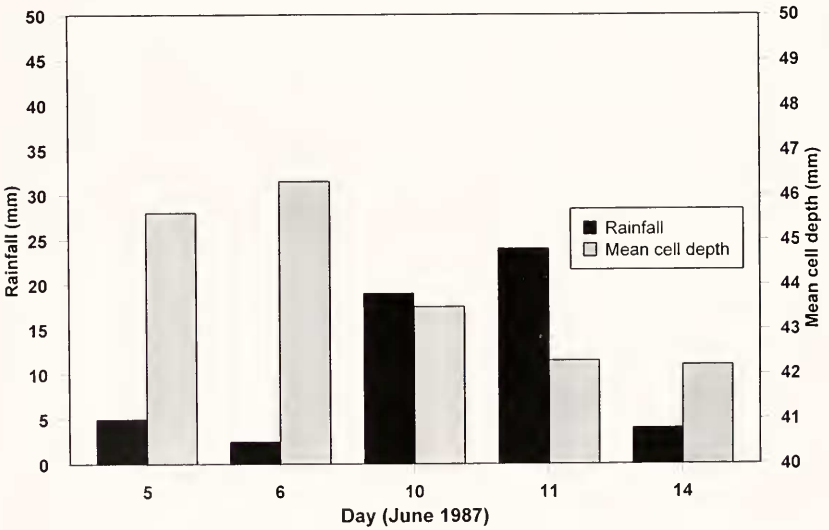

Fig. 2. Amount of rainfall and mean cell depth in *Oxybelus bipunctatus* study area, 5-14 June 1987. Amount of rainfall is a measurement from previous day(s) and/or night(s).

The average air and mean cell depth temperatures on these mornings at 1100 hrs (EDT) were only 17.2° C (15-18° C, n=6) and 21.1° C (18-22° C, n=6), respectively.

Soil moisture line. The soil moisture line was indistinguishable from the overlying sand on days when it rained heavily. On non-rainy days, this line was clearly visible and cells were invariably excavated below it in moist sand. There was an imperfect positive correlation between soil moisture line and cell depth (Fig. 3). In some nests, the soil moisture line to cell depth value was more disparate than in other nests (Fig. 3).

Cell depth. Females excavated fewer and deeper nests in drier soil. They dug clumped and shallower nests in moister soil. Nests excavated in neither dry nor wet sand were intermediate in depth and more evenly distributed than nests in wet or dry sand (Figs. 1, 2). Mean cell depth and amount of rainfall from the previous day(s) and/or night(s) were inversely related (Fig. 2). In early to mid-June, slight increases or decreases in mean cell depth followed corresponding decreases or increases, respectively, in the amount of rainfall (Fig. 2). For example, shallowness in mean cell depth on 10, 11 and 14 June was probably linked to a substantial amount of rainfall and increased soil moisture content on 10-11 June. Nests excavated during 5-14 June under natural conditions had, on average, shallower cells ($\bar{x}$=44.4±5.38 mm; n=88; Fig. 2), albeit not significantly so, than control plot nests dug on 16-24 June ($\bar{x}$=47.3±6.29 mm; n=67; Table 1). This difference probably was due to the different amounts

Table 1. Cell depth of *Oxybelus bipunctatus*, control and experimental plots, 16-24 June 1987.

Site Information		Cell Depth (mm)		
Date	Plot	n	Range	Mean
6/16/87	NC	10	38-59	46.6+5.99
6/16/87	SC	10	38-58	47.8+6.23
6/17/87	SC	17	38-56	45.8+5.54
6/17/87	SE	10	26-45	37.8+8.16
6/17/87	NC	15	35-55	48.1+5.79
6/17/87	NE	11	37-65	45.2+8.22
6/24/87	NC	15	34-63	48.2+7.88
6/24/87	NE	12	39-61	47.6+6.77

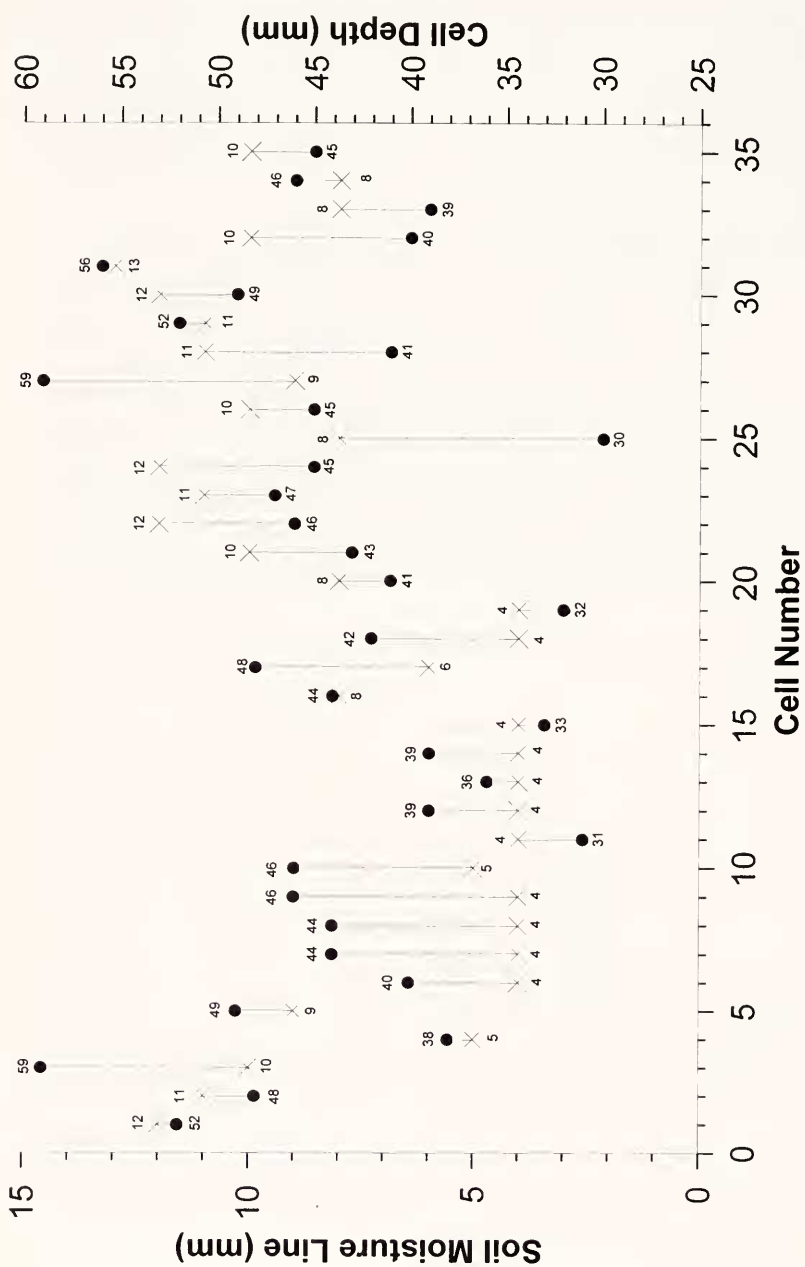

Fig. 3. Difference between soil moisture line and cell depth in *Oxybelus bipunctatus* nests, 5, 14 June 1987. Measurements are in mm below sand surface, X representing soil moisture line and ● cell depth; vertical line indicates difference in the two measurements.

of rainfall during these times of the month (5-14 June, 54.5 mm; 16-24 June, 45.7 mm).

Mean cell depth for 16 June NC and SC nests was similar ($t=0.0793$, $df=18$, $\alpha>0.20$) (Table 1). On 17 June, wasps excavated significantly deeper cells in SC than in SE ($t=3.0415$, $df=25$; $\alpha<0.01$) (Table 1). There was no significant difference in mean cell depth between two samples each comparing NC and NE nests (June 17, $t=1.0572$, $df=24$, $\alpha>0.20$; June 24, $t=0.0397$, $df=25$, $\alpha>0.20$), although the wasps did excavate slightly shallower cells in both NE plots (Table 1). All nests (n=12) in NE excavated on 24 June were clustered downslope in the SW corner in moist sand (Fig. 1).

DISCUSSION

Few studies on fossorial sphecid wasps considered the influence of relative soil moisture on cell depth. Moisture gradient influenced cell depth throughout the nesting season in *Microbembex nigrifrons* (Provancher). Deeper cells were dug in drier and shallower cells in wetter sand (Alcock and Ryan 1973). Soil moisture level was related to cell depth in *Ammophila harti* (Fernald). Cells excavated in drier sand remained deeper than those dug in wetter sand regardless of generation of wasp (Hager and Kurczewski 1986). Cell depth and, less so, soil moisture line closely followed an increase or decrease in relative soil moisture, as governed by the amount of rainfall, throughout the nesting season in *Oxybelus bipunctatus* at one locality in central New York (Kurczewski in prep.).

In the present study, both soil moisture line and cell depth were inversely related to the amount of rainfall. There was, however, an imperfect positive correlation between soil moisture line and cell depth with some values being more disparate than others, even in perfectly flat sand. Regardless of possible flaws in the experimental design, shallower cells were usually excavated in moister and deeper cells in drier sand. However, only one control versus experimental plot sample was conclusive. In this comparison, SE cells in artificially watered sand were excavated at significantly shallower depths than SC cells.

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watermilfoil. Based on the observation of adult activity in May and the presence of numerous eggs, we believe *E. lecontei* is established in Indiana and we anticipate that the biology of *E. lecontei* in Indiana will be very similar to that reported by Sheldon and O'Bryan (1996).

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